

Chapter 1

Prospects and Results from the AFP Detector in ATLAS

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In 2016 one arm of the AFP detector was installed and first data have been taken. In parallel with integration of the AFP subdetector into the ATLAS TDAQ and DCS systems, beam tests and preparations for the installation of the 2nd arm are performed. In this report, a status of the AFP project in the ATLAS experiment is discussed.

1. Introduction

ATLAS¹ is a general purpose detector operating at the LHC². Apart from the main apparatus a new group of forward detectors is installed in order to extend the scope of possible measurements. The existing Zero Degree Calorimeter¹ mounted 140 m away from the nominal interaction point (IP) is dedicated to the measurement of the forward neutrons and photons. The Absolute Luminosity For ATLAS (ALFA)³ detector, situated about 240 m from IP, is devoted to the measurement of elastic scattering. The latest detector is named ATLAS Forward Proton (AFP)⁴. It is dedicated to studies of diffractive processes and its main purpose is to measure forward protons.

2. The AFP Detector

The AFP detector is designed to consist of four stations, two on each side of ATLAS along the beam-pipe. The stations are located ± 206 m and ± 214 m away from the ATLAS IP. Each station is equipped with Roman

Pots which allow the horizontal movement of the detector components and their insertion into the beam-pipe. This enables precise positioning of the detector in the vicinity of the beam. Positions of the stations and detectors result in acceptance of protons with relative energy loss of about $\xi = (E - E')/E \in (0.02, 0.12)$, where E and E' are incoming and outgoing proton energies, respectively.

Each station is designed to house four planes of the tracking detectors. Far stations (i.e. the ones placed at ± 214 m) will be equipped with time-of-flight counters.

Silicon pixel detectors are used for tracking. Each plane contains 336×80 pixels of size $50 \times 250 \mu\text{m}^2$. The modules are similar to the ones used in ATLAS IBL⁵ and are radiation hard. The detectors are tilted by 14° with respect to the vertical direction, which makes that majority of the protons pass two pixels.

In the Technical Design Report⁴ the time-of-flight counters are stated to have time resolution of 10 ps or better and efficiency of at least 90 %. This enables measurements in the environment of about 50 interactions per bunch crossing on average and allows to identify the vertex from which the proton measured in AFP originates with resolution of 2.1 mm in the longitudinal direction. Moreover, the detectors have to be fast enough to provide the trigger signal, which is challenging due to their location at 214 m away from the ATLAS detector. The main purpose of the time-of-flight detectors is to identify the vertex from which the proton measured in AFP originates. Thus they are crucial in runs with many interactions per bunch crossing (high pile-up) in standard runs, in which AFP is expected to take part in 2017.

AFP installation is staged. The first stage during which one arm of the AFP detector “AFP 0+2” was installed took place before data taking in 2016. The installation of the other arm, “AFP 2+2”, is scheduled for the beginning of 2017.

3. AFP 0+2

The first stage of the AFP detector installation covered placing two stations in the LHC tunnel. Both stations were situated on the same side of ATLAS. They were equipped only with tracking detectors. The stations had to pass the LHC qualification, because the detectors are inserted into the beam-pipe. Additionally, the detector control (DCS), data acquisition (DAQ) as well as trigger systems had to be integrated with the ATLAS central

systems. As a result of successful installation and almost flawless detector operation it was possible to collect first data for physics analysis already in 2016, although it was not initially planned.

In 2016 AFP participated in two physics runs. In these special runs the pile-up was low. In total almost 500 nb^{-1} of integrated luminosity was collected. The detectors performed very well. In Fig. 1 the number of hits per silicon detector plane based on the 2016 data is presented. In most of the events the signal is registered in two pixels which is exactly what was expected due to the tilt of the silicon planes. A strong correlation between the neighbouring planes can be observed in Fig. 2 where the pixel row index in the second plane versus the first plane is plotted for events with up to two pixel hits in a layer.

A natural physics program for this configuration contains the studies of single diffractive dissociation (SD). In this process a forward proton and a hadronic system well separated in rapidity are present in the final state. The cross section of this process is relatively large which enables studies using the low pile-up data. So far the ATLAS collaboration did not publish any result of the SD measurement with identification of a forward proton, which allows to distinguish between single diffractive and low-mass double diffractive dissociations. The AFP detector delivers a unique possibility of performing such measurements in the kinematic region of the relative proton energy loss in the range $\xi \in (0.02, 0.12)$. Moreover, it will provide access to so far unavailable kinematic variables like the four-momentum transfer in the proton vertex $t = (P - P')^2$, where P and P' are the incoming and outgoing proton four-momenta, respectively.

4. AFP 2+2

The final AFP installation is scheduled for early 2017. It includes placing of two new stations in the tunnel, installation or replacement of the current tracking and time-of-flight detectors. These actions have to be followed by the LHC qualification procedure. Additionally, the time-of-flight detectors have to be integrated with the ATLAS trigger system. The full instrumentation of AFP will allow data taking in special low pile-up runs as well as in standard runs with high pile-up.

This configuration, just like the AFP 0+2 one, is good for studies of single diffractive dissociation in special runs with clean environment. However, the possibility to measure forward protons on both sides and collect high integrated luminosity in standard runs gives access to central diffractive

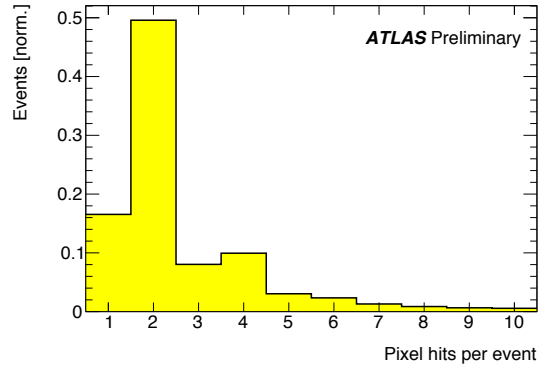


Fig. 1. Number of hits in a plane based on 2016 data.⁶

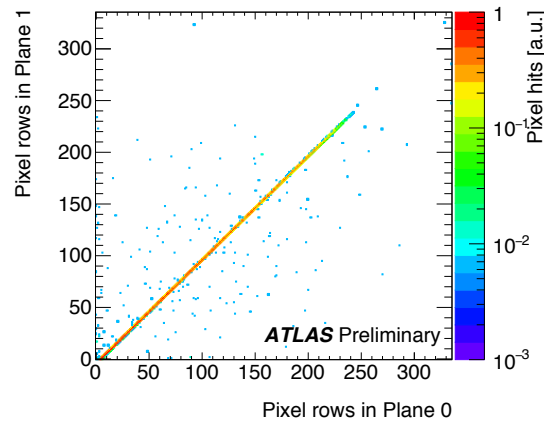


Fig. 2. Correlation of pixel rows between first and second planes of tracking detectors based on 2016 data.⁶

processes with small cross-sections. In addition, information about event's full kinematics is provided. A reach diffractive physics program, including exclusive dijet production or central diffractive photon-jet production, aims at better understanding of the nature and structure of the colour singlet exchange. However, the program is not limited to this kind of studies only. There are also plans to investigate photon-induced processes for which the

proton tag provides a very good background rejection. The exclusive lepton production measurements⁷ can be improved. The possibility to discover new physics lies e.g. in the studies of anomalous quartic couplings.

5. Summary

All operations of the AFP detector, dedicated to measurements of the forward protons mainly originating from diffractive interactions, are on schedule. The first stage, AFP 0+2, was finished in 2016 and the data for physics analysis were collected in special runs with low pile-up. The second and final installation stage, AFP 2+2, will be finished in 2017. The timing detectors installed then will allow the measurements of the forward protons in standard runs with high pile-up, thus providing access to central diffractive processes characterised by small cross-sections. The usefulness of the AFP detector is reflected in its reach physics program presented in the “Technical Design Report for the ATLAS Forward Proton Detector”⁴.

6. Acknowledgement

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